An extremely rich group of starbursts and AGNs at a z=3.1 proto-cluster core

Hideki Umehata
(Open Univ. of Japan/Univ. of Tokyo)

Outline

0. Introduction
   - Target field: z=3.09 proto-cluster core
   - ALMA Deep Surveys in a biased region

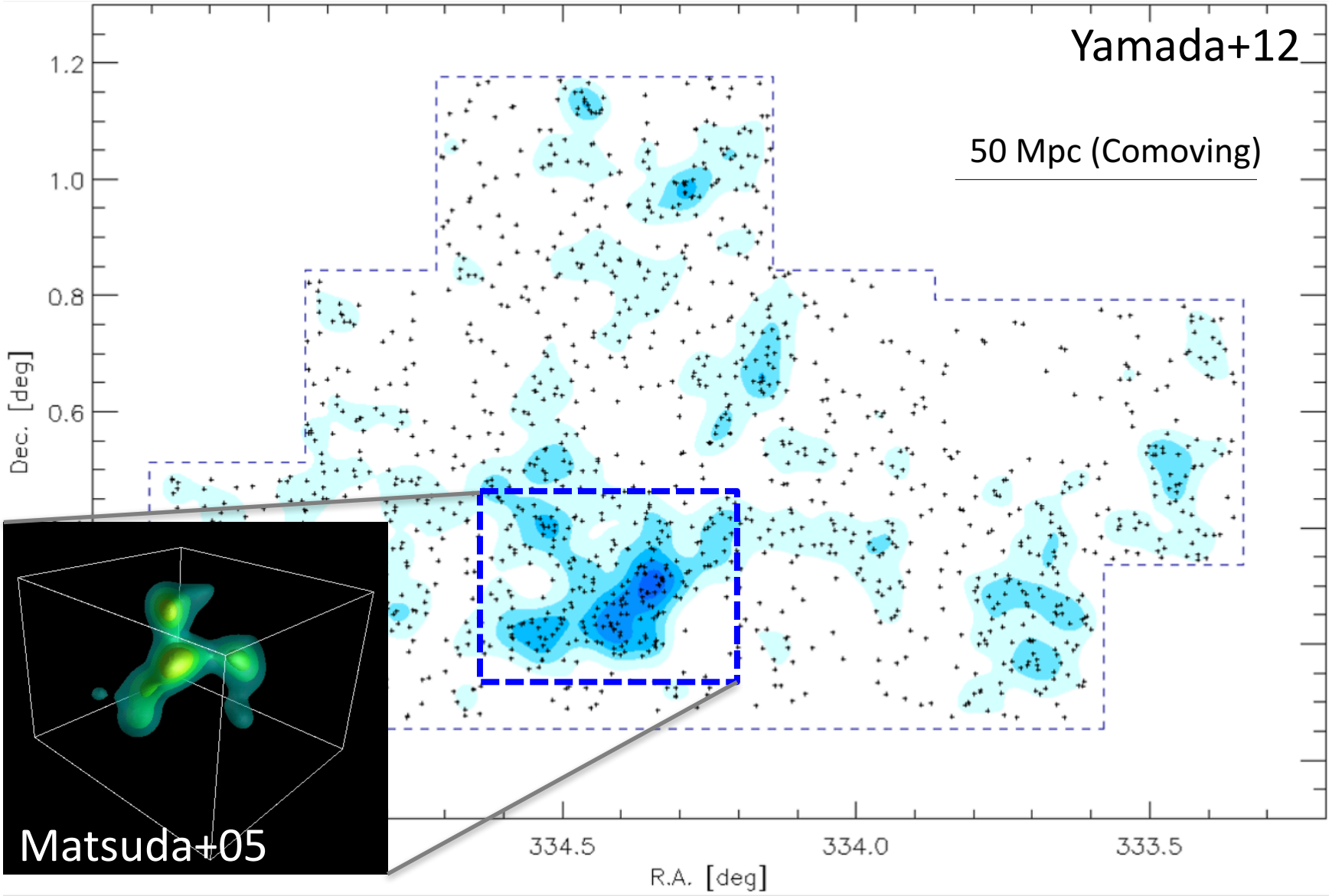
1. ALMA Deep Field in SSA22: ADF22
   - 'unbiased' census in a biased field: cold dust

2. molecular ALMA Deep Field: mADF22
   - 'unbiased' census in a biased field: molecular gas

3. Summary

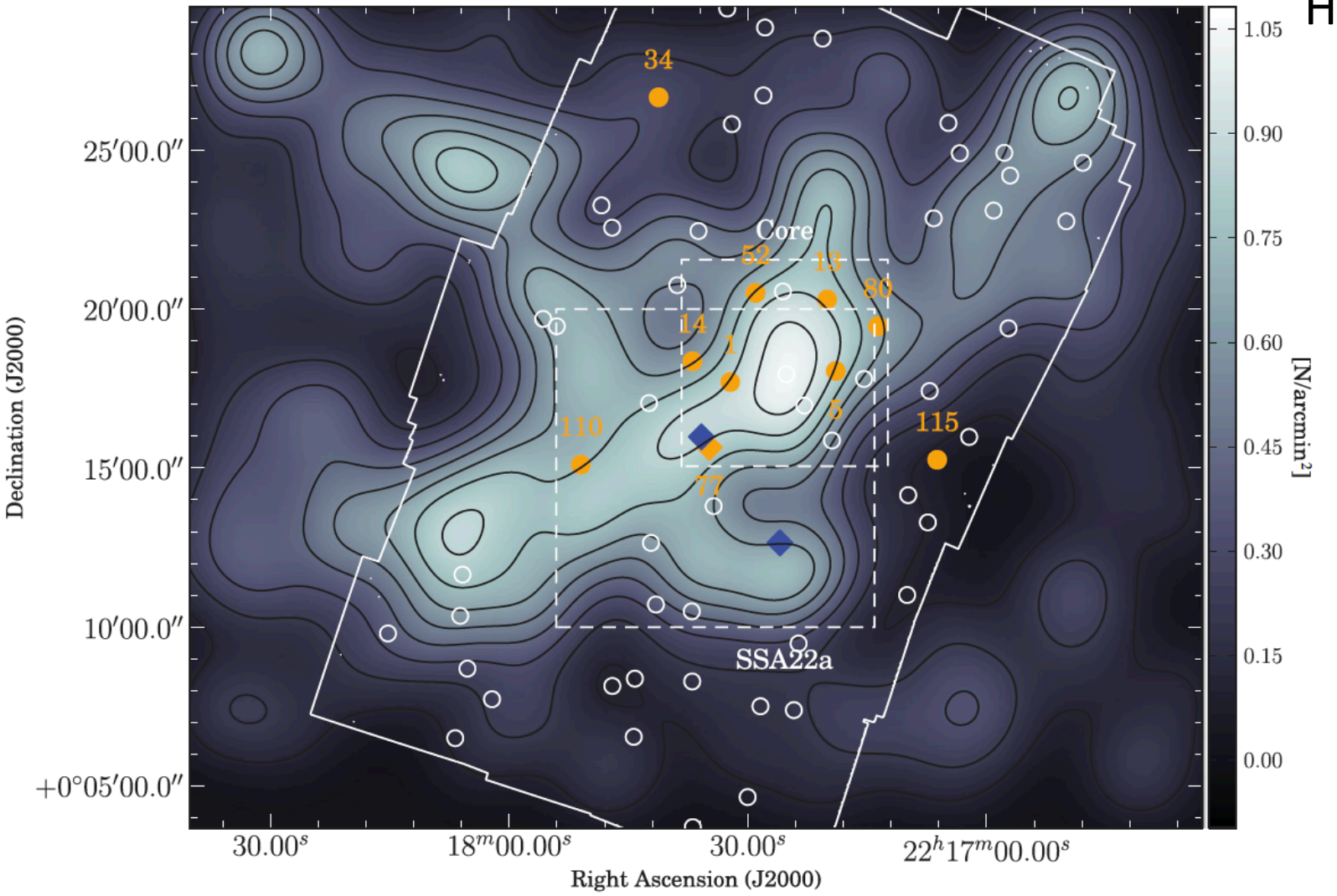
Target: SSA22 Proto-cluster

§ **Surface number density map of z=3.09 LAEs**



SMGs in the galaxy overdensity?

HU+14

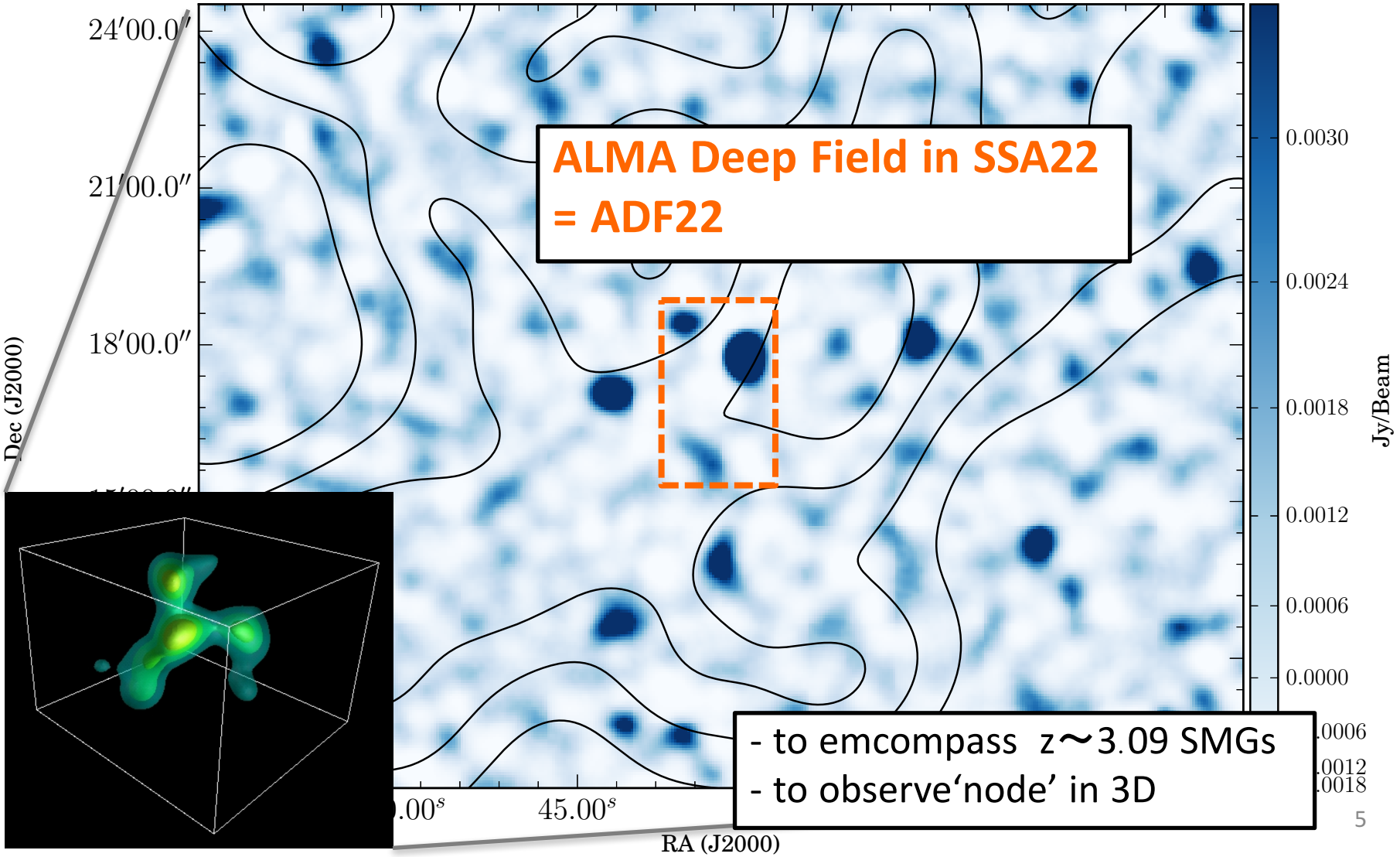


- Yellow (Blue) circles: z~3.1 AzTEC (SCUBA) SMGs
- SMGs appears to reside in the proto-cluster.

New mm window: ADF22

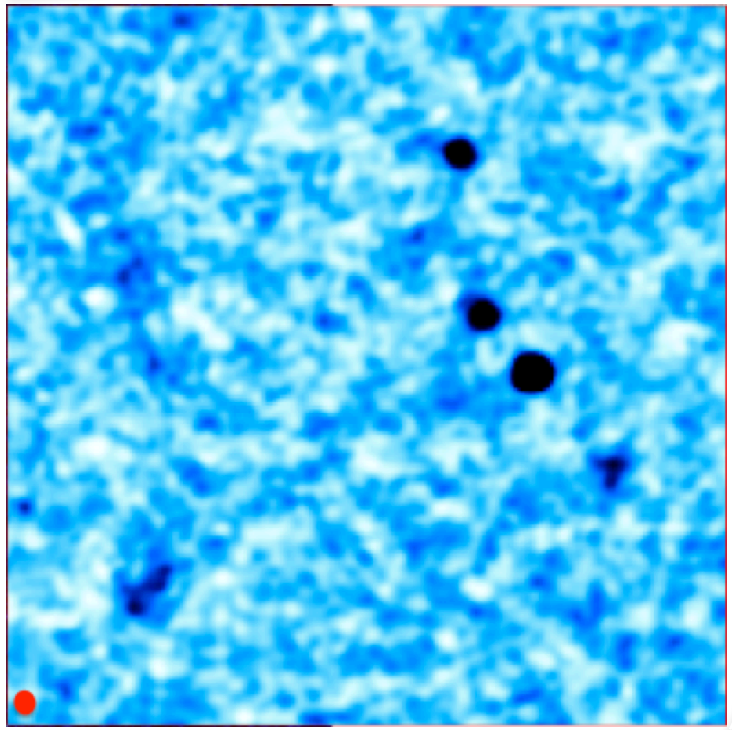
§ **AzTEC 1.1mm map of the SSA22 field**

Tamura e al. 2009; HU et al. 2014

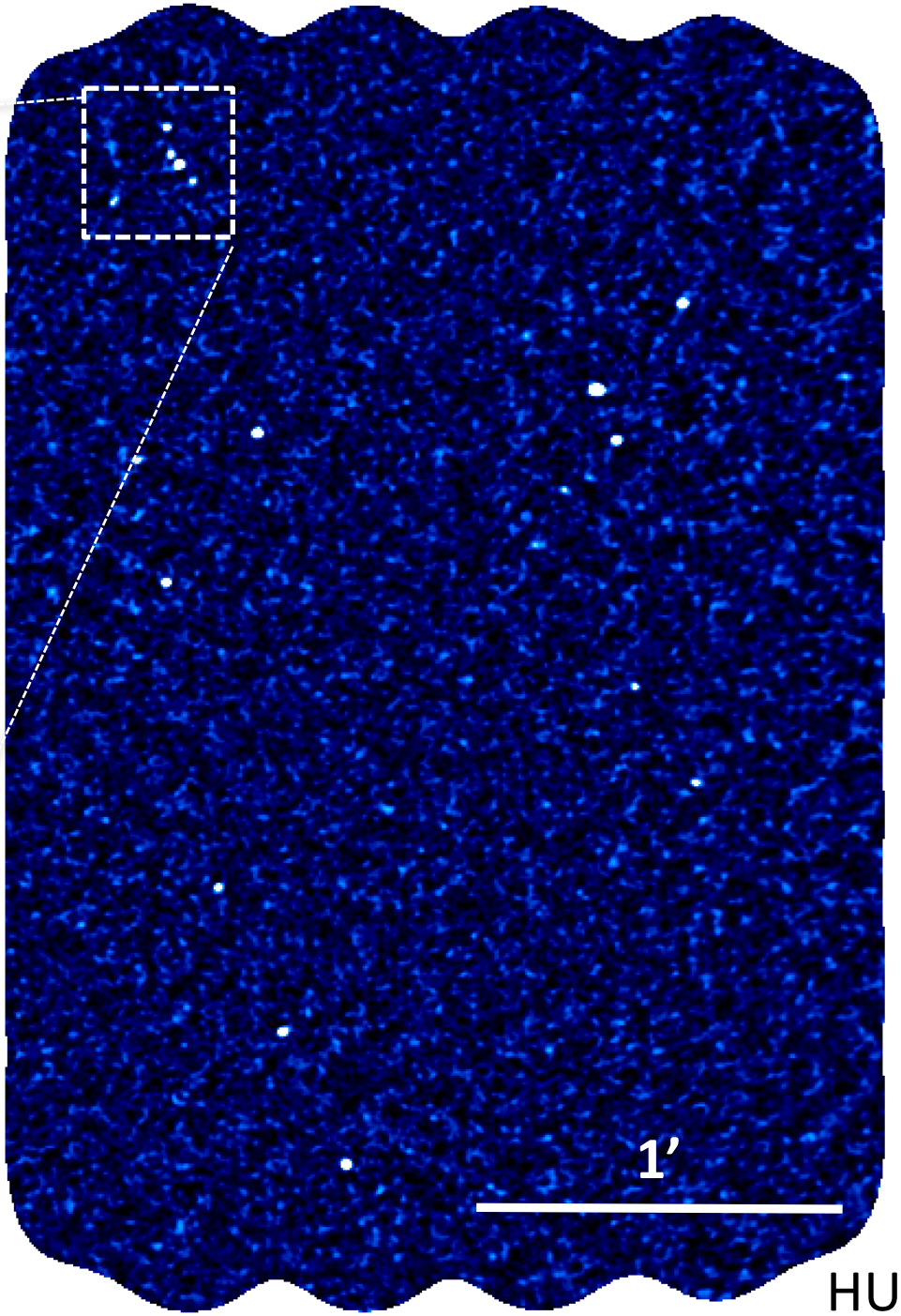


1. ALMA Deep Field in SSA22 at 1.1mm

1.1mm Map



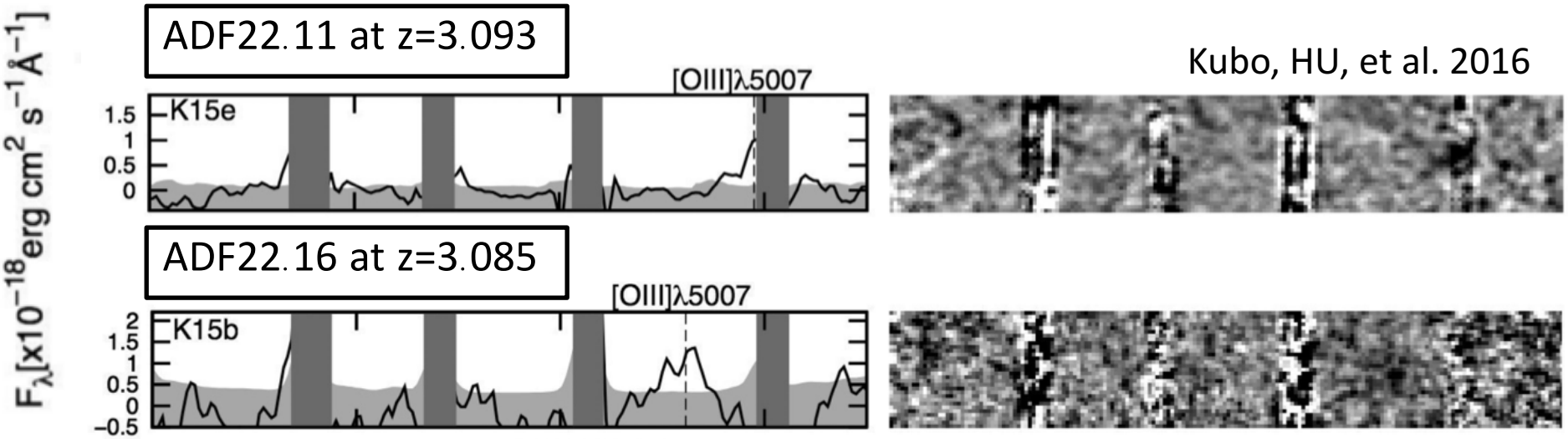
Frequency	**263 GHz (1.14mm)**
Area	**7 arcmin^2**
Angular res.	**0.5”**
RMS	**60 uJy/Beam**
Detection	**18 at 5sigma**



HU+17b

[OIII]5007 by MOIRCS

Redshifts of ALMA sources



Kubo, HU, et al. 2016

CO(3-2) by LMT

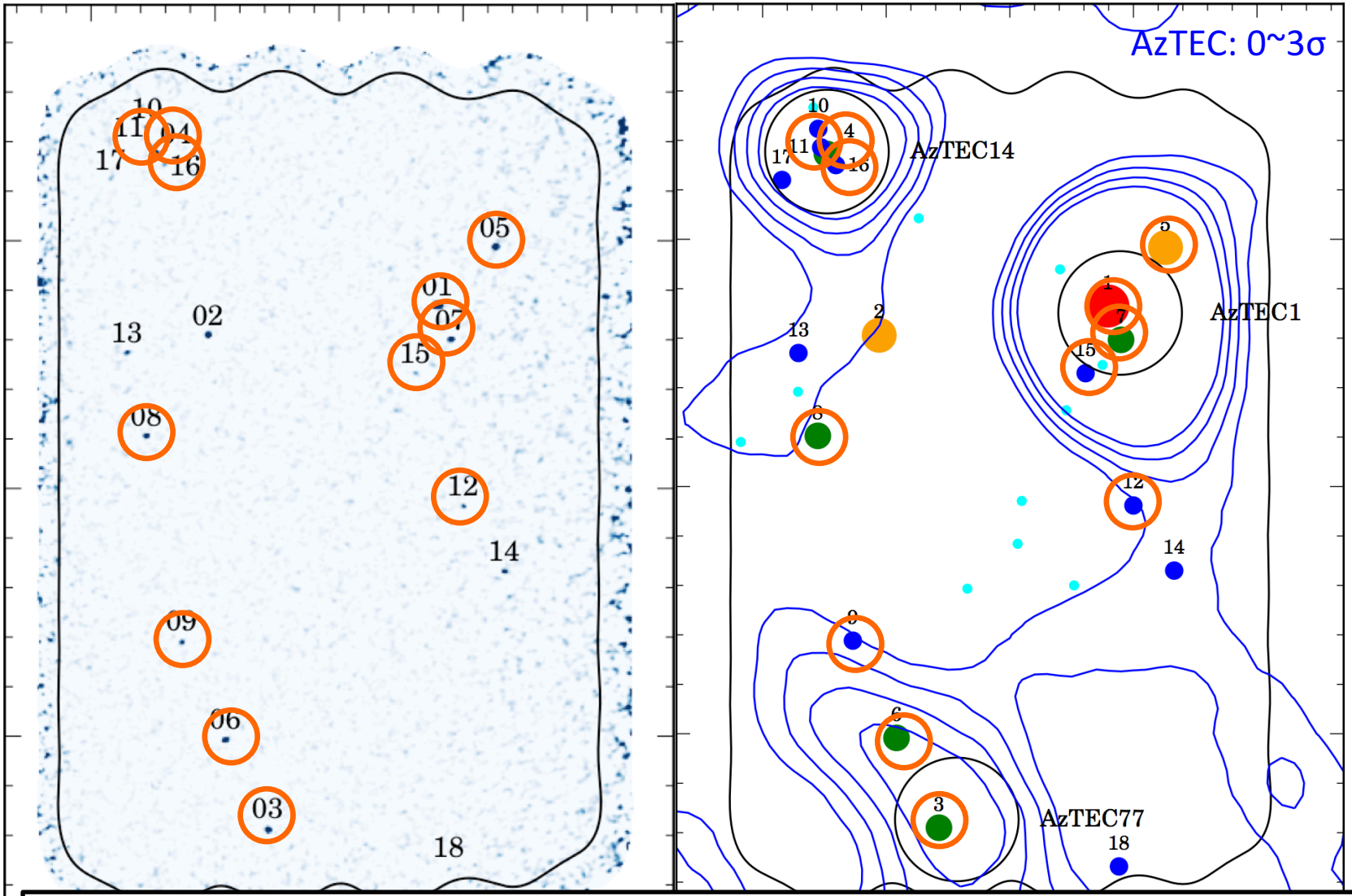
ADF22.1 at z=3.0915

Yun et al. in prep

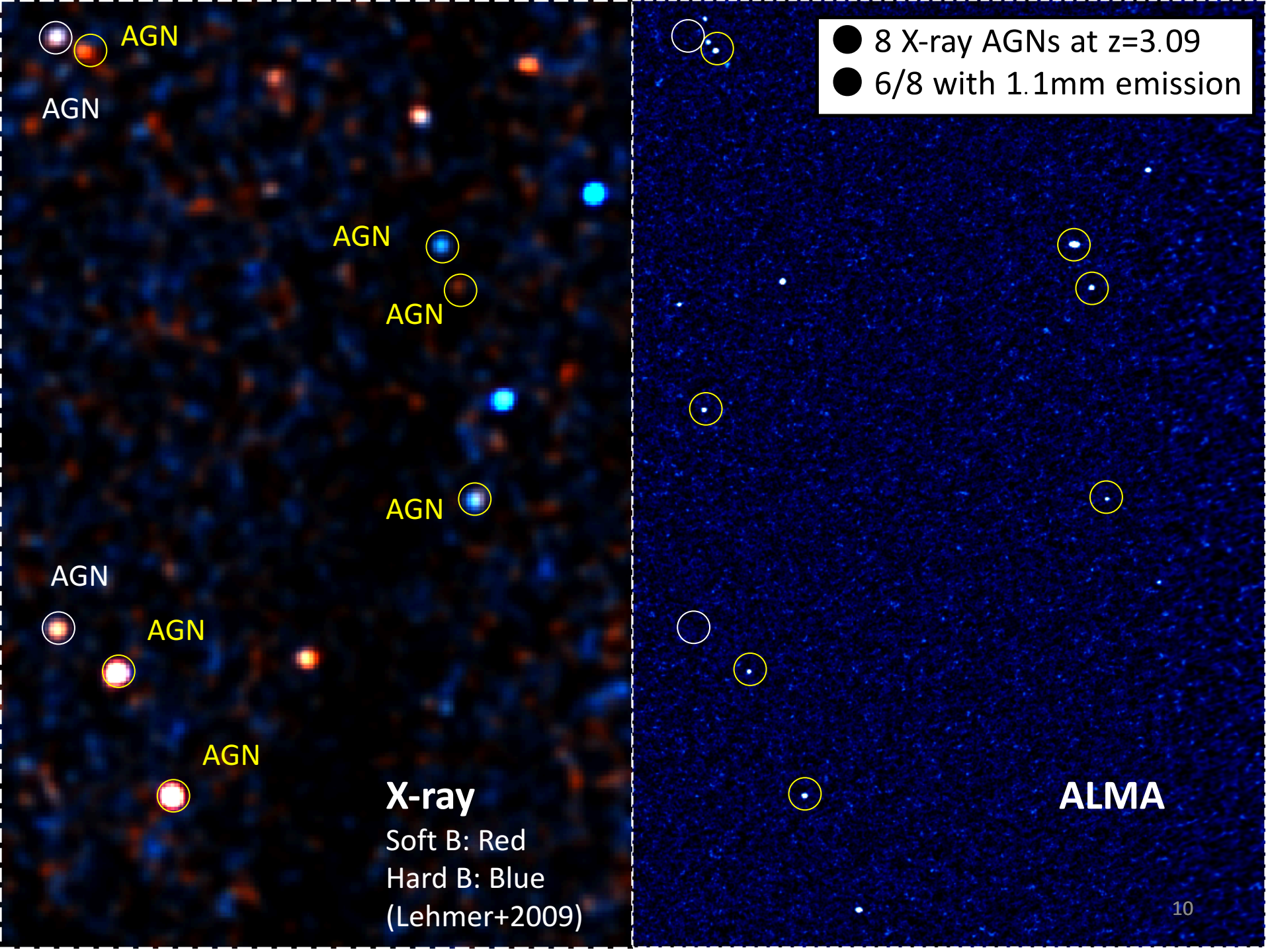
- 12/18 ALMA sources are at z=3.085-3.097.
- 4/18 may be at z=3.1, but no secure spec-z.
- One is at z=2.1, another is at z>4.

Multiplicity of ‘classical’ SMGs

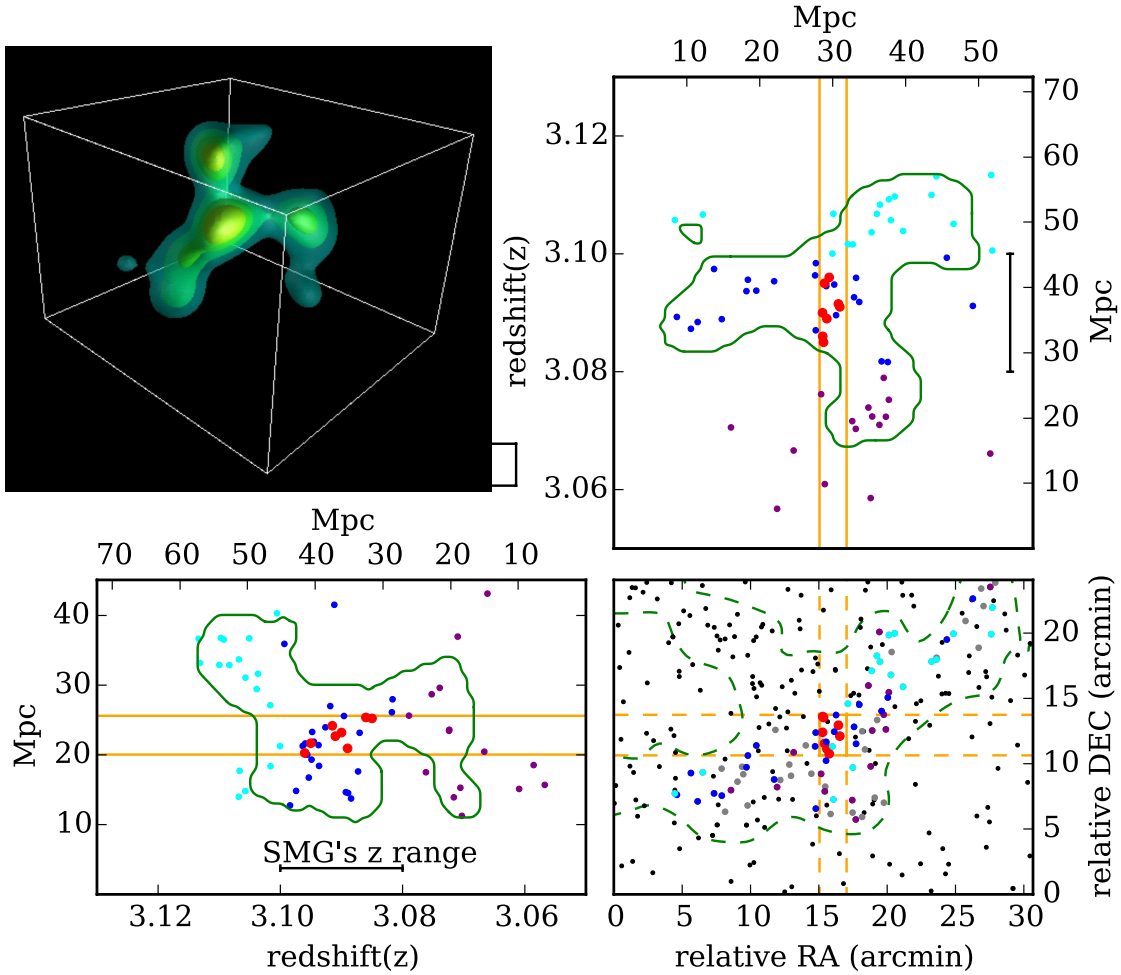
HU+17b



- Multiple SMGs consist some of bright ‘classical’ SMGs.
- Physically associated SMG groups can account for some portion of them.


AGN
AGN
AGN
AGN
AGN
AGN
AGN
X-ray
Soft B: Red
Hard B: Blue
(Lehmer+2009)
8 X-ray AGNs at z=3.09
6/8 with 1.1mm emission
ALMA

SMGs in the cosmic structure



HU+15
(cf. Matsuda+05)

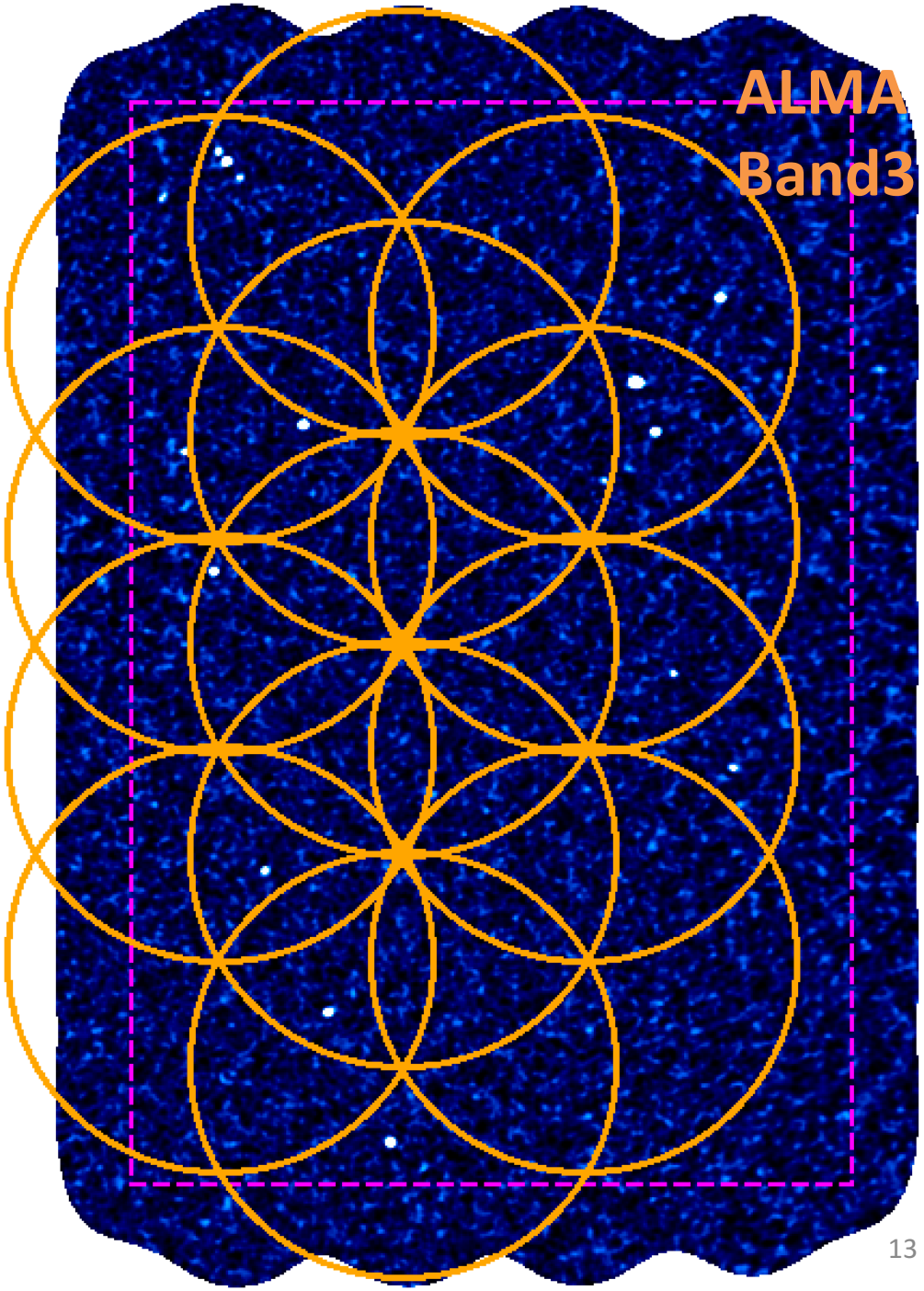
- An extremely rich SMG cluster are found in the node of a cosmic web.
- The most active star-formation and SMBH growth simultaneously occur at the center of the z=3.1 proto-cluster.

2. ALMA Deep Field in SSA22 at 3mm (for CO(3-2))

Observations

Frequency	**84~86 GHz**
Area	**~6 arcmin^2**
Angular res.	**0.9” x 0.8”**
Detection	**8 at 5sigma**

- CO(3-2) at z~3.09 is covered with one spw.



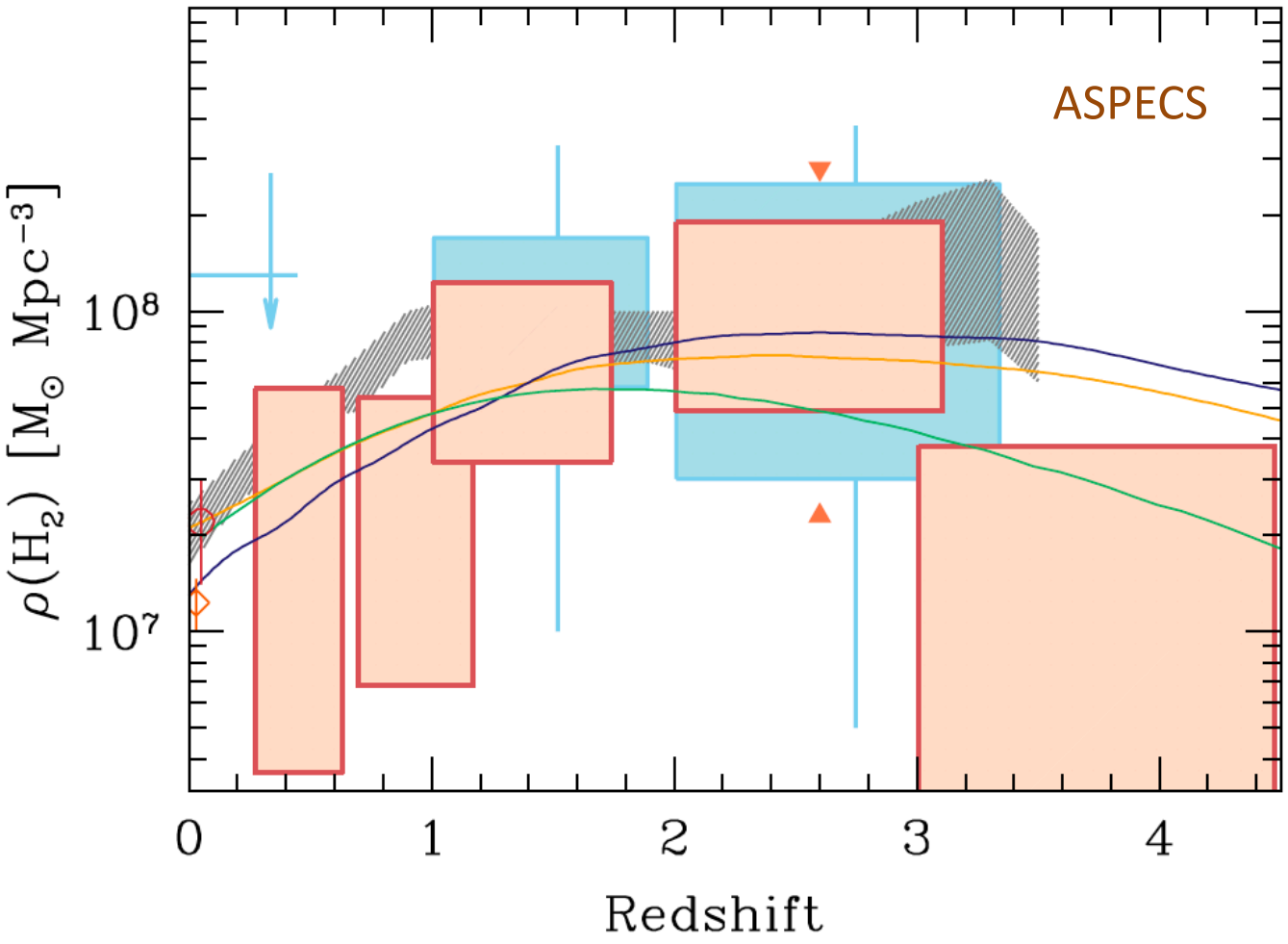
CO(3-2) Spectra of ALMA sources

HU+17c, in prep

- CO, [CII] lines are strongly required for such galaxies.

Molecular Gas Mass Density

★ ADF22



Decarli+17

● Molecular gas mass density is also high at the proto-cluster core.
(We assume αCO=1.0 Msun (K km^-1pc^2)-1) (Bothwell+13))

CO Luminosity vs IR Luminosity

HU+17c, in prep

Summary

● SSA22 Field is a nice target to investigate the co-evolution of galaxies and cosmic structure. A 2'x3' 'contiguous' region at the center is covered by ALMA band 6 and band 3.

● We found lots of dusty starburst galaxies at z_spec=3.09. This means that

- Multiplicity is caused by 'physically associated' dusty star-forming galaxies at least at the z=3.09 proto-cluster.

- Both intense star-formation and rapid SMBH growth occur at the node of the 3D cosmic structure simultaneously.

● The 'blind' CO(3-2) survey is uncovering the molecular universe. For instance,

- Molecular gas mass density at the proto-cluster core appears to be much higher than the general field.

- Bright SMGs in ADF22 show lower SFE than typical SMGs. Rich gas supply may partially account for the over abundance of SMGs.